

# PROCEEDINGS

AMERICAN SOCIETY  
OF  
CIVIL ENGINEERS

SEPTEMBER, 1955



DISCUSSION OF  
PROCEEDINGS PAPERS

517, 700, 740

POWER DIVISION

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Printed in the United States of America*

**Headquarters of the Society**  
33 W. 39th St.  
New York 18, N. Y.

PRICE \$0.50 PER COPY

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This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N.Y.

Discussion of  
"RECENT TRENDS IN HYDRAULIC GATE DESIGN"

by D. A. Buzzell  
(Proc. Paper 517)

D. A. BUZZELL,<sup>1</sup> M. ASCE.—Mr. Streiff's comments, as might be expected, reveal an exhaustive knowledge of the history of hydraulic gate development, here and abroad. A study of the history of hydraulic gates, such as was attempted in the Corps of Engineers' survey, will show that it is difficult to draw rigid and fixed conclusions regarding these structures. Several attempts have been made to so correlate the results of this survey that such conclusions could be reached but when all of the variants were taken into consideration, this was found to be impracticable. The principal factors were hydraulic design of the water passages, design of the gate leaf including metals used, and actual usage of the facility. Many of the gates examined had practically never been used or had functioned only briefly during flood routing or for emergency closure. Naturally such gates had a favorable history as only periodic painting and lubrication would preserve them indefinitely. Severe corrosion in polluted waters, as on the Pennsylvania rivers, had long been known and the liberal use of high-alloy metals had supplied the answer. All of the trouble at Denison was due to faulty fabrication, and after suitable repairs the original gates are serving satisfactorily. In a few cases faulty operative procedures had injured gates.

One firm conclusion reached by the survey was that high-head gates can be mounted within the water passages. Most of our earth dams are so equipped and we have had up to 17 years of successful operation of roller-train gated outlets, normally closed to hold a conservation pool, but frequently operated during flood routings. These gates are usually exposed to the erosive action of bed load. They have an excellent history. The Fort Randall gates will be operated at all heads but in such a manner that they will not be held at the one low-head point where some vibration occurs. The objections to end outlet gates are the greater initial cost of the pressurized conduit and more elaborate stilling basin even though there is some saving in the control tower. There is also some apprehension regarding the safety of a long pressurized conduit through a high earth dam.

The Corps has come to rely more and more on model tests in formulating the design of hydraulic control works. The technique of model building and testing has been much improved in recent years and instances of the prototype failing to live up to the model are exceedingly rare.

The deflection-bearing device described by Mr. Latham is an ingenious method of economizing on a gate intended for a special use. It could not of course be used for an operating gate.

Mr. Holt's remarks, together with those of Mr. Streiff, regarding heavy discharges over ogee crests only show that truth can be stranger than theory.

<sup>1</sup> Corps of Engrs., Washington, D.C.

Some of our engineers have acted as observers in the galleries of concrete dams during heavy spillway discharges and have been alarmed by the vibration then observable. Some of our early model tests also predicted this vibration. Whether because of better models or the gaining of more experience, the fears regarding deep spillway discharges have largely been dissipated.

Mr. Chetty has summarized the principal improvements which have been made in gate leaf and mounting design. The writer is familiar with the Davis Dam gate design and pleased to hear of its favorable action. The Corps adopted the eccentric pin to insure longer seal life and to make certain that there would be no vibration at part gate openings. Successful performance of the Davis gates should encourage the designer to use this simpler and more economical design. The writer would prefer the eccentric gate for very high heads as small seal leaks can cause "wire-cutting" when under high pressure.

The Corps usually provides two gates in tandem and provisions for an emergency upstream bulkhead handled by a hoist or mobile crane. If this upstream closure arrangement is entirely dependable for closure against full flow through the outlet, there would seem to be justification for omission of the second internal gate. In many of our projects rapid closure, in case the operating gate failed when open, is so important that we have been unwilling to accept the risk of the much longer time required to make the bulkhead closure, but there are undoubtedly projects where no such hazard would be involved. The cost figures given are for one gate only. Conduit liners are placed only over the areas where model tests indicate danger from erosion or cavitation. These liners are usually of cast steel but there are no known criteria for thickness.

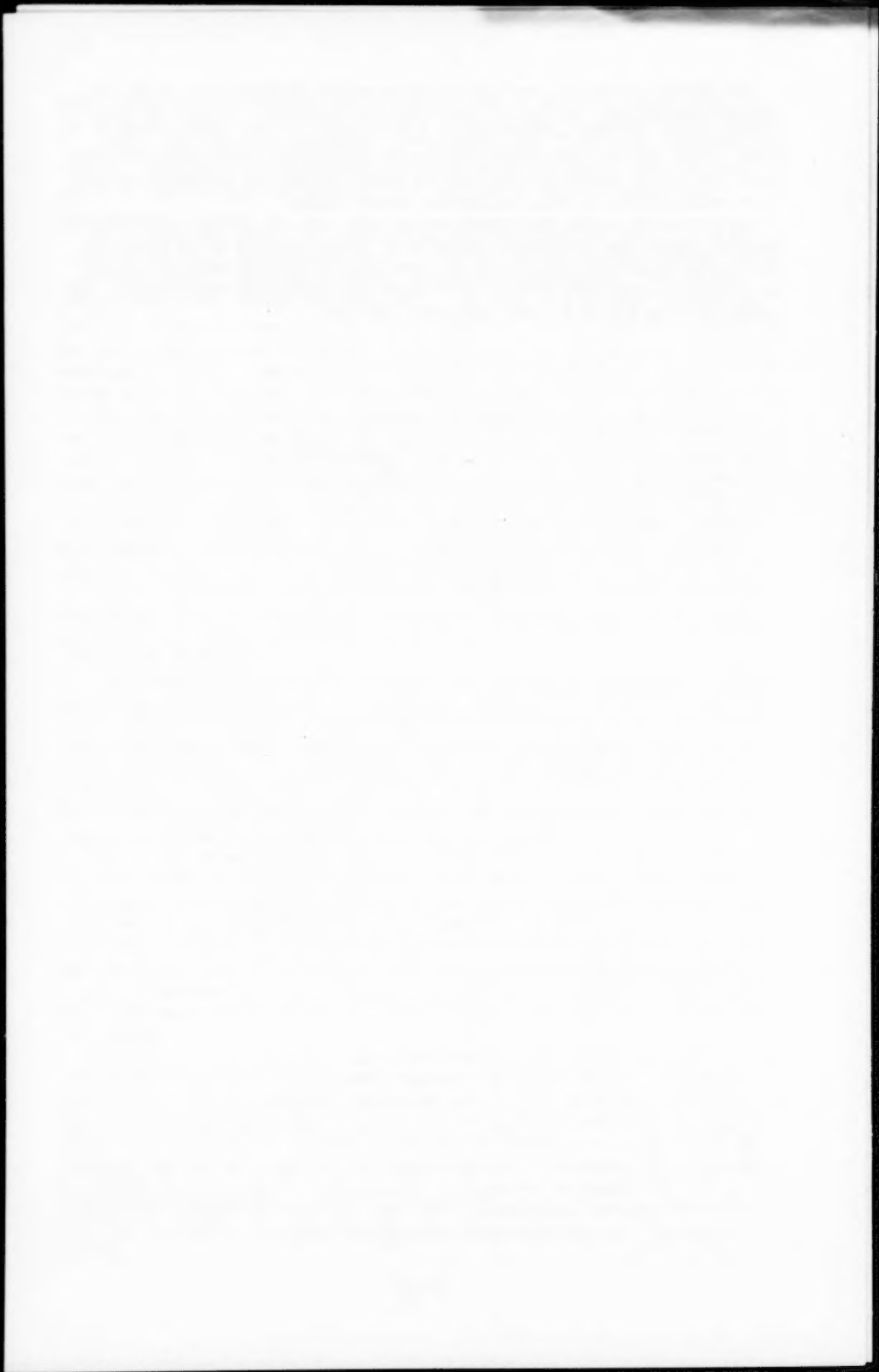
The Detroit fixed-wheel, welded-body gate proved to be expensive but this may be an isolated instance. We have used fixed-wheel gates for power intakes and elsewhere and the writer has always felt that this type has been neglected. When wheel loads become excessive, the designer is forced to roller trains but the roller-train gate has the disadvantage of exposing a great area of rollers, links and bearing plates to the mercies of the stream. The fixed-wheel gate with sealed bearings will suffer far less from the contamination of bed load, polluted water, and marine life.

The writer would consider a fixed, double flanged wheel gate with sealed roller bearings as the first choice for power intake closure. The Detroit sluice gate (Fig. 4) was not economical and proved to have the hydraulic disadvantage of the spreading jet causing some erosion of the conduit walls. A steel liner to cover the area of impingement would have prevented this. The Meridian gate (Fig. 3) is believed to be both economical and hydraulically sound. A mechanical hoist is usually cheaper than a hydraulic hoist but the hydraulic hoist can be closed after power failure and it tends to dampen out vibrations.

Mr. Weber's remarks are appreciated as we have closely studied the Bureau of Reclamation's work and frequently profited from it. The writer has no doubt that the hydraulic slide gate can be used in larger sizes than the one we have arbitrarily set as our limit. The critical factor, in the opinion of our designers, is the bearing pressure. This side bearing can never be uniform over the area and the allowable intensity, considering the deviations in gate fabrication, is a question for the designer's judgment. The Grand Coulee experiments showed that very high intensities of bearing were permissible for certain metallic combinations providing that the bearing was uniform.

The writer's previous remarks cover possible simplification of the eccentric tainter gate. He cannot agree with the discussor concerning crest tainter gates. We use no wider piers for these gates, our standard width being 8 feet, and unit bid prices show up no higher for the inclined arm type. Total cost of the entire spillway will be found less for the inclined-arm gate which will be found in some old wooden tainter gates.

As previously noted, the writer agrees fully with Mr. Weber regarding the wheeled rather than the roller type of gate. When the load is too heavy for the flanged wheel on a crane rail, we have gone to flat rim wheels bearing on a massive embedded bearing plate which permits much higher loads. The bushed bearing should be used whenever possible.



Discussion of  
"PERMEABILITY, PORE PRESSURE AND  
UPLIFT IN GRAVITY DAMS"

by Roy W. Carlson  
(Proc. Paper 700)

BRYANT MATHER.<sup>1</sup>—Active consideration of the problems discussed in this paper is needed and, it is hoped, will be stimulated by its publication and distribution. The paper was prepared in November 1951 for the Office, Chief of Engineers, U.S. Army, revised by the author in May 1952, and published in March 1954 as Appendix A to Waterways Experiment Station Technical Memorandum No. 6-380.<sup>2</sup>

The laboratory tests initiated by Professor Raymond E. Davis for the Corps of Engineers have been continued by the Waterways Experiment Station. The work done at the University of California described in the report by Davis, referenced by the author on pages 700-3 and 700-4 of the paper, and subsequent work up to 1951 by the Waterways Experiment Station, was reported in a paper by Herbert K. Cook.<sup>3</sup> Results of these tests through an age of two years are given in the Waterways Experiment Station report<sup>2</sup> and through five years age in a revision thereof.<sup>4</sup> A summary of average results is tabulated on the following page.

1. Civ. Engr. (Concrete Research), Concrete Div., Waterways Experiment Station, Corps of Engrs., U.S. Army, Jackson, Miss.
2. Corps of Engrs., Waterways Experiment Station, Permeability and Triaxial Tests of Lean Mass Concrete, Vicksburg, Miss., March, 1954.
3. "Permeability Tests of Lean Mass Concrete," Proceedings, A.S.T.M., Vol. 51, 1951, pp. 1156-1165.
4. Corps of Engrs., Waterways Experiment Station, "Revision A-Permeability of Concrete at Five Years Age," Supplement to T.M. 6-380, Vicksburg, Miss., July, 1955.

SUMMARY OF PERMEABILITY DATA<sup>a</sup>  
200-PSI TESTS ON 14-1/2- x 15-IN. CONCRETE CYLINDERS

Mix	CF bags/cu yd	FM	W/C	Permeability Value K <sup>b</sup>				
				3 mo.	1 yr <sup>c</sup>	1-1/2 yr	2 yr	5 yr
A	2.00	2.50	0.80	685	133	348	190	206
B	2.00	2.25	0.86	479	143	418	81	92
C	2.25	2.25	0.84	662	214	411	290	100
D	2.25	2.85	0.67	926	120	106	161	99
E	2.25	2.50	0.72	830	228	216	152	128
F	2.25	2.25	0.76	439	156	92	148	157
G	2.50	2.85	0.60	574	139	202	72	75
H	2.50	2.50	0.66	687	83	140	111	194
I	3.00	2.85	0.50	200	56	203	57	66
Av				609	141	237	140	124

a. Taken from Table 3 of reference 5.

b. Permeability values K given in terms of  $\frac{\text{cfs} \times 10^{12}}{\text{ft}^2 (\text{ft head/ft length})}$

c. 3-mo specimens retested at 1-yr age. All other results are for initial testing.



Discussion of  
"THE HIGH-SYPHON CIRCULATING WATER SYSTEM  
FOR MERAMEC PLANT"

by Chas. E. Buettner and Paul A. Pickel  
(Proc. Paper 740)

R. T. RICHARDS,<sup>1</sup> A.M. ASCE.—Messrs. Buettner and Pickel have highlighted a most important phase of circulating water system design, the utilization of maximum siphons. In short, this amounts to the maximum reduction in pumping head with the attendant savings in pumping costs. Tremendous volumes of water are moved in all large steam stations, and the cost of pumping is appreciable.

Two important related issues were mentioned; first, the possibility of water column separation and secondly, the need for adequate air removal. While both these problems are accentuated by very high siphons, they are not serious enough to nullify the use of the high siphon.

Water column separation will very often occur following the tripout of the circulators (due, for example, to power failure). This phenomenon may occur even with negligible siphons. The writer's own studies have indicated that the surges following the rejoining of the water columns are not often of a serious nature in circulating water systems; however, if theoretical analysis indicates that excessive surges might occur they can be fully controlled by the installation of vacuum breakers properly located on the conduit. To check this specific problem of water column separation the writer has recently completed a series of pump tripout tests at a 160,000 kw 2 unit generating station in a southern state. The operating siphon for this station with all pumps in service was about minus 21 feet of water. Following simultaneous tripout of all pumps water column separation took place at the condenser as predicted by theoretical analysis, and the resulting surge pressures recorded on high speed gages were well within the range of the system design calculations. A 3rd unit (125,000 kw) is now under construction at this station with trial operation scheduled for August 1955. This unit will be on a new conduit installation which has been designed for a maximum siphon of slightly over 30 feet. It is expected that the surge pressures which may be experienced in this 30 foot siphon layout will be no greater than those predicted and proven for the 21 foot siphon system recently tested. A high siphon is only one of many factors contributing to water column separation.

The necessity for proper air removal is a second major consideration brought out by Messrs. Buettner and Pickel. This is particularly important since air binding may result in a marked reduction in system flow. Where conduits slope downward the loss of head due to air accumulations on the slope may be nearly as great as the entire vertical drop of the slope. At one station having a long slope in the discharge line the excess loss of head exceeded 19 feet when the vacuum pumps at the top of the slope were shut down.

<sup>1</sup> Hydr. Engr., Ebasco Services, Inc., New York, N.Y.

All but 2 feet of effective siphon was lost. Yet a small 6 cfm air pump taking suction from several points on the slope was adequate to keep the system fully primed. At another station located on the Mississippi River the loss was nearly 15 feet, 7 feet of which was in sloping pipe leaving the condenser discharge water box. Generally speaking the cost of providing suitable air removal facilities is insignificant when compared to the benefit to be derived from the saving in pumping head. As Messrs. Buettner and Pickel pointed out the maximum practical siphon is primarily determined by the commercial limits of air removal equipment, not by the occurrence of undesirable hydraulic phenomena at high vacuums.

E. A. RUDOLPH,<sup>2</sup> A.M. ASCE.—The writers of this paper have done an excellent job of presenting a successful solution to a problem that plagues all designers of thermal power plants on our great inland rivers.

Those of us familiar with the Mississippi have learned that it must be treated with respect, even when we attempt to shunt away from it for the briefest interval of time only a small fraction of its great volume of flow for some purpose of our own. The care with which each detail of the problem is presented bespeaks that respect on the part of the writers. Perhaps because the river seems to have the power to humble all of man's efforts Messrs. Buettner and Pickel have not, I believe, brought out fully the magnitude and importance of the problem.

Circulating water is the life blood of a modern thermal power plant. Cut off the circulating water supply and the plant will function for just about the same number of seconds that a man would function if the circulation of his blood were cut off.

Here are some comparative figures to illustrate the size of the project. On the peak day in 1954 the Meramec circulating system delivered 202 million gallons of water to the condensers.

The peak day for the water supply to the entire city of St. Louis in 1954 was 284 million gallons. When the next unit already in the planning stage is installed at Meramec the plant will require more water for condensing purposes than is required to supply the entire city of St. Louis.

Coal is delivered for the plant from barges on the river at the rate of 2,500 tons per day and that is a fairly sizeable operation in itself. The circulating water system delivers 800,000 tons of water per day. Small wonder then that every effort is made to reduce to a minimum the head against which this huge mass of water must be moved.

It is here, of course, that the first conflict between construction and operating cost must be resolved. Structural costs would have been increased as the pumping head was decreased and pumping costs would have been increased as structural costs were decreased.

The obvious compromise was to seek the lowest combination of annual operating cost and annual structural carrying charges.

This required the close cooperative effort of both the structural and mechanical engineering groups. The happy results attest the value of such cooperation.

The paper is perhaps unique in that it is being presented to a group of civil engineers rather than a group of mechanical engineers before whom most papers on thermal power plants seem to be offered. Recently there have been a number of papers on the civil engineering features of thermal

<sup>2</sup> Engr., Cons. Dept., Union Elec. Co., St. Louis, Mo.

power plants. These have been rather general in nature, however, and do not go into the detail presented by the present paper in regard to a specific problem. The writers of the paper are to be commended on their able presentation of a problem and its solution. As they point out some surprises were encountered, but none were of a nature which affected the basic purpose of the system which was developed. The writer is certain that other power-plant designers will benefit by the experience which writers of this paper have so carefully set out.

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